

## PSYCHOLOGY

## How Do Scientists Think?

David Lagnado

Have you ever wondered what goes on inside scientists' heads when they formulate a grand theory? Or when they decide what hypothesis to test? How does this differ from the mundane reasoning involved when you explain why your car won't start or choose a birthday present for a relative? More generally, do scientists use the same cognitive mechanisms available to us all (supplemented with formal, conceptual, and technological tools)? Or does scientific thinking require more specialized cognitive abilities, available to only a talented few?

If you are interested in such questions, then Gregory Feist's *The Psychology of Science and the Origins of the Scientific Mind* is the book to read. As the title suggests, Feist (a psychologist at the University of California, Davis) argues the case for a new discipline of "psychology of science" and explores the evolutionary and historical roots of scientific thinking. The first half of the book gives a brief history of three dominant areas in which science itself has been the object of study (history, philosophy, and sociology of science) and reviews a wealth of research implicitly engaged in the psychology of science. This research is divided along traditional lines (biological, developmental, cognitive, personality, and social psychologies), and Feist makes a convincing case for their inclusion in the new discipline. However, his survey lacks an overarching framework and reads more as an assortment from subordinate disciplines. (The desired unification is not helped by the traditional divisions already in place.) If we are envisioning a new discipline, now is a great time to rethink the classic taxonomy—if not to replace it, at least to give it a sound and logical explanation.

What of the origins and precursors of scientific thought? How did we move from preliterate hunter-gatherers who eat their meat raw to sophisticated reasoners with a taste for relativity theory and fine cuisine? In the

second half of the book, Feist charts this progression with originality and insight. His speculations on the origins of scientific thinking are particularly impressive and draw well on recent cognitive psychology. He identifies several core components of thought—observation, categorization, pattern recognition, hypothesis testing, and causal thinking—and argues that these were progressively augmented as scientific thinking passed from the preverbal stage

through to the explicit research we have today. Critical developments along the way included explanatory thinking (greatly aided by the advent of language), measurement, mathematics, and finally the hallmark of modern science, the experimental method.

This account is well argued and innovative, but more could be made of the dynamic interplay between the key components. For example, both observation and categorization are hypothesis-driven (1) and can be influenced by prior causal thinking (2). This implies that these components co-develop rather than arise in an incremental fashion. Further support for such co-development is provided by the recent emphasis in cognitive neuroscience on action-based representations (3). Thus it appears that our internal models of the world are heavily shaped by the demands of effective action. Indeed, "motor cognition" could be added as a key component in the preverbal stage of scientific thought.

Notably absent from the book are any discussions of the formal or normative models that scientists (or everyday reasoners) ought to use and how these models relate to descriptive models of scientific reasoning. Although it is common to distinguish how people actually reason (descriptive) from how an ideally rational person would reason (normative), both play crucial roles in current psychological research. Normative

models serve both as standards against which to appraise human performance and as a framework for understanding cognition (4, 5). For example, there is a growing movement in cognitive psychology and neuroscience that advances a Bayesian perspective on the mind (6).

Indeed, one of the appeals of causal maps (which are discussed by Feist in his chapter on cognitive psychology) is that they are formally well defined and normative (7). The question of whether people use fully fledged causal graphs (and Bayesian methods), or instead use simplifying heuristics that approximate these norms, is contentious. But there is little doubt that formal models are critical to the development of cognitive models. Moreover, the psychology of science has a special stake in these issues, because the status of normative models is itself keenly debated in current philosophy of science.

Another topic of concern is Feist's attempt to prescribe guidelines for recognizing scientific talent (and its consequences for education and selection policies). He makes much of correlational studies that allow predictions of scientific achievement from intelligence and personality tests and demographics. Such an emphasis is worrying for two reasons: First, there are well-known problems with using correlational studies as a basis for policy interventions. Correlation does not imply causation, and these studies may include all kinds of confounding factors. Second, even if the predictors are valid precursors for the prototypical scientist, would we really want to risk excluding less stereotypical thinkers? Einstein would have fared pretty poorly in terms of early college achievements.

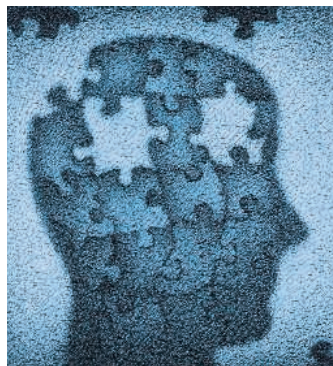
Lastly, there is a hint of paradox in introducing a new discipline to bridge the gap between related disciplines. Once the new discipline is established (complete with specialized conferences and journals), it runs

the risk of reducing rather than increasing cross-disciplinary talk. There are now three independent groups that need to share information rather than two, so new bridges must be built, and so on. In the case of the psychology of science, this is not just a theoretical worry. The subdisciplines of psychology already suffer a lack of integration and cross-fertilization; adding another discipline (however much its content spans the divide) might simply add to the problem.

**The Psychology of Science and the Origins of the Scientific Mind**

by Gregory J. Feist

Yale University Press, New Haven, CT, 2006. 336 pp. \$38, £25. ISBN 0-300-11074-X.



The reviewer is in the Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK. E-mail: d.lagnado@ucl.ac.uk

The barbarism of specialization looms anew.

In spite of these worries, *The Psychology of Science and the Origins of the Scientific Mind* succeeds on many levels. Feist pulls together a vast range of psychological research with clarity and insight, and he advances an intriguing framework for the cognitive origins of scientific thinking. The book makes a strong case for an integrated study of the psychology of science.

#### References

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10.1126/1132467

## PHYSICS

# The Universe, Too Quickly Toured

Sean M. Carroll

There's no reason why everyone shouldn't understand the basics of quantum mechanics and relativity. These two cornerstones of 20th-century physics have become a basis for our deepest understanding of reality, as well as of great practical importance to familiar technologies from lasers to the global positioning system. And, despite their reputations for being somewhat abstruse and inaccessible, the basic points of each theory can be stated simply enough that an interested person with no technical background in physics should be able to understand them. At a time when science seems both more central than ever and more removed from our everyday world, it is certainly worth the effort to share what we've learned

**The Quantum Zoo**  
A Tourist's Guide to the  
Neverending Universe

**Marcus Chown**

Joseph Henry Press  
(National Academies  
Press), Washington, DC,  
2006. 212 pp. \$24.95, C\$27.95.  
ISBN 0-309-09622-7.

about the workings of nature with interested nonscientists.

We should therefore welcome books like Marcus Chown's *The Quantum Zoo: A Tourist's Guide to the Neverending Universe*. Chown's work is an admirable attempt to delve into the mysteries of these two great theories, quantum mechanics and relativity, and express them in terms that an intellectually curious nonexpert can understand. And for the most part the book succeeds. Chown (a science writer who trained as a physicist) has a pleasant writing style and a facility with simple metaphors and analogies that helps bring difficult concepts into sharp focus.

The book is divided into two sections: "Small Things" and "Big Things." In the former, as you might guess, he covers the quantum world, explaining the crucial ideas of superposition and interference, and braving difficult topics such as the uncertainty principle, entanglement, and the collapse of the wave function. Chown moves easily from historical examples such as Young's double-slit experiment and Rutherford's scattering to modern issues such as quantum computers and teleportation. In the second section,

devoted to relativity, he swiftly covers the basics of spacetime and relativity, gravitation, and cosmology. The appropriate hot topics are mentioned, if briefly: black holes, string theory, inflation, and dark energy. The brevity of the text is not a shortcoming; not every popular book needs to be a massive and comprehensive tome. The

popular audience at which *The Quantum Zoo* is aimed should learn a lot from reading the book and enjoy themselves in the process.

And yet, there is a sense in which the book is a disappointment. There are other books out there, after all, that deal with the topics of quantum mechanics and relativity. To stand out from the crowd, any new entry should have something distinct to offer. It might be the unique insight of a true master of the field, as we find when Richard Feynman writes about quantum electrodynamics or George Gamow writes about the



**Tunneling site.** Proton tunnelling allows hydrogen fusion in the Sun to occur "even at the ultralow temperature of 15 million degrees."

Big Bang. Or it might be an in-depth examination of new and exciting developments in a particular discipline. Or, for that matter, it might just involve bringing a storyteller's eye and a gift for narrative to illuminate a forbidding complex of ideas.

Unfortunately, *The Quantum Zoo* isn't really distinguished in any of those ways. Chown is a fine explainer, but he doesn't take us over any ground that others haven't trod before. For example, after a good explanation of bosons and fermions takes us up to the connection between spin and statistics, Chown simply admits that this

"brings us to the end of what can easily be conveyed without opaque mathematics." Later, after foreshadowing about how superfluid helium can do strange things like crawl up the sides of a container, the book never actually explains why that happens. Dark energy is not explained any more deeply than "the repulsive force of empty space." After whetting our appetites for more substantive explanations, we are left feeling a little unsatisfied.

The primary shortcoming of the book seems to be the lack of some specific point to the project. The subtitle, *A Tourist's Guide to the Neverending Universe*, gives an indication of the unfocused nature of the text. I suspect that Chown could have written an interesting and useful book about quantum mechanics, starting with the basics and going into some detail about modern developments in atomic and molecular physics, quantum information theory, and quantum computation. Or, alternatively, an interesting and useful book about relativity, concentrating on some specific aspect such as gravitational waves, black holes, or dark energy. Instead, Chown's book is competent but uninspiring, a somewhat superficial look at the foundational theories of modern physics. The explanations are clear, and the interested reader will be able to learn quite a lot. But there is not quite any reason to choose *The Quantum Zoo* from among the other titles on the popular-science shelf.

10.1126/1130369

The reviewer is at the Physics Department, California Institute of Technology 452-48, 1200 E. California Blvd, Pasadena, CA 91125, USA. Web site: <http://preposterousuniverse.com>